Development of a Template for Vessel Hull Inspections and Assessment of Biosecurity Risks to the Kermadec and sub-Antarctic Islands Regions

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1. Introduction

Vessel biofouling is one of the main contemporary vectors for the introduction and spread of marine non-indigenous species (NIS). Most of the >200 marine NIS established in New Zealand waters are thought to have arrived on the hulls of ships, a pattern reported from locations around the world (Hewitt et al. 1999; Eldredge and Carlton 2002; Kospartov et al. 2008). Merchant, fishing, passenger and recreational vessels continue to arrive in New Zealand from overseas locations with NIS attached to their hulls (Inglis et al. 2010; Piola and Conwell 2010). To manage the biosecurity threats associated with vessel biofouling MAF Biosecurity New Zealand (MAFBNZ) has recently released a draft Import Health Standard for consultation, which specifies the requirements to be met for effective management of risks associated with biofouling on the submerged parts of vessels arriving in New Zealand from international waters (MAFBNZ 2010).

The Department of Conservation (DOC) is concerned about the biosecurity risks associated with biofouling on vessels visiting New Zealand's sub-Antarctic islands, and the remote sub-tropical Kermadec islands. These locations (from hereon collectively referred to as "the islands") are currently visited by commercial cruise ships, fishing vessels, navy vessels and privately or commercially operated sailing yachts. Vessel biofouling is thought to be the mechanism behind introductions of NIS globally to isolated high-value locations, including sub-polar and polar latitudes (Lewis et al. 2003, Lewis et al. 2005, Barnes et al 2006; Lewis et al. 2006; Tavares and De Melo 2006; Lee & Chown 2007, 2009).

Three options are available to prevent the introduction of marine NIS to New Zealand's high-value islands. Improvements in vessel hygiene measures, such as regular antifouling paint renewal and/or hull cleaning, can be used to ensure that vessels visiting these locations do not carry biofouling organisms. Alternatively, when a clean hull has not been achieved, a risk assessment process can be used to ensure that only those vessels with biofouling that does not pose a biosecurity risk to the islands are allowed to travel to them. A third option which denies access to the islands is also a possibility but is likely to be met with resistance from the shipping sector.

The present system used by DOC under the Reserves Act is simple and, in theory, effective. It requires *any* vessel intending to land on New Zealand's sub-Antarctic islands to undergo an initial hull inspection at the owner's expense. An entry permit to land on the sub-Antarctic islands' is granted only when no biofouling organisms other than marine biofilm ("slime") are detected on the hull. Presence of more substantial biofouling results in failure of the inspection. The vessel is then given the options of abandoning its intention to visit the islands or to undergo a second, more comprehensive inspection (again at the operator's expense) during which specimens are collected and identified. An entry permit is granted if none of the species detected on the vessel are considered by recognised experts in taxonomy, biology and biogeography to pose a biosecurity risk to the islands' marine ecology. Currently no such system is in place for the Kermadec islands.

The current system has several shortcomings, which were identified and discussed during recent meetings between DOC and NIWA:

1. There is no transparent framework accessible to vessel operators that clearly defines DOC's expectations on hull condition, provides information on how to meet these expectations, and identifies the process that non-compliant vessels should follow;
2. The absence of such a framework means that vessels are not able to take pro-active measures to ensure they meet DOC's expectations prior to entry into New Zealand. The time required for inspection and risk assessment to take place (1-4 days depending on circumstances) can result in a delay to the vesselss schedules and corresponding financial losses to the vessel operators. This is particularly a problem for commercial cruise ships that have very tight schedules with short periods of stay in each port (often < 1 day).
3. No provisions currently exist for vessels to seek exemption from biofouling inspections if they have achieved the required standards of hull hygiene (i.e., there are no incentives for dedicated hull maintenance);
4. Biofouling inspections are currently carried out without the use of a standardised sampling and quality assurance protocol. This means that the quality of inspections may vary and that an unknown number of species on a hull may not be detected, compromising the effectiveness of the inspections;
5. No information or assistance is provided to vessels that fail the biosecurity inspection on how to efficiently mitigate this problem in New Zealand. This is particularly an issue for cruise ships under international charter that are on a tight schedule and for whom delays may have serious financial consequences.
6. The current system is applied only to vessels wanting to land passengers on the islands. No restrictions exist for vessels that want to access waters within 1000 m of the mean high water spring tide (MHWS) line.

DOC is in the process of preparing a regional coastal plan for the Subantarctic and Kermadec Islands under the Resource Management Act 1991. As a part of that plan they wish to address the risk of introduction of marine NIS to New Zealand's high-value islands presented by all vessels visiting close into shore, as well as those that land passengers.

To assist DOC to develop a framework for inspection and assessment of biofouling risk on vessels intending to visit the sub-Antarctic or Kermadec islands, NIWA was contracted to develop:

(i) A <u>decision support tool</u> that can be used by DOC to determine: (a) which vessels will require inspection and how frequently, and (b) the level of biosecurity risk posed by vessels that do have biofouling on their hulls, and

(ii) Templates for hull inspections of vessels intending to visit the sub-Antarctic or Kermadec islands. The templates include: (a) inspection protocols for the initial presence of fouling, (b) sampling protocols for hull biofouling inspections, (c) laboratory protocols for specimen handling, preservation and dispatch to taxonomic specialists, and (d) instructions for taxonomic specialists on the biological and biogeographical information required to allow an informed assessment of the biosecurity risk posed by the vessel to the sub-Antarctic and Kermadec islands.

The following sections describe the decision-support tool and risk assessment templates developed for this contract. The templates and tool were designed to be made available on the DOC website. Their purpose is to introduce, describe and illustrate the expectations that DOC has with regard to biofouling on vessels intending to travel to the islands, how these expectations can be met, and the process vessel operators that do not meet these expectations can expect to have to go through before a Coastal Permit is issued. We have sought to make the process as transparent as possible so that vessels intending to visit the islands can complete a self-assessment prior to sailing for New Zealand and, where necessary, take measures to prevent delays in the issue of a Coastal Permit.

2. Decision support tool

DOC aims to prevent the introduction of marine NIS to New Zealand's offshore islands. This is a complex task, as visitors to the islands include a wide range of groups including private boaters, commercial fishermen, DOC staff, researchers, the NZ Navy and cruise ship operators. For some of these visitors, significant delays could result in substantial financial cost. It is, therefore, important that the approach chosen effectively prevents transport of high-risk biofouling to the islands, but does not impose a logistical or financial barrier to the visits. This can be best achieved by working with the shipping and fishing industries and recreational boating community to actively reduce biofouling risks to the islands.

To assist this process, clear information is needed on: (i) what DOC intends to achieve and why, (ii) DOC's expectations for vessels intending to travel to the islands without delays caused by inspections, (iii) the process of determining the biosecurity risk of vessels, (iv) the consequences of non-compliance and, (v) management options for achieving compliance. In providing this information vessel operators must ensure they meet minimum standards if they want to avoid delays in obtaining access to the coastal marine area of the islands.

Ideally the management framework should *incentivise* vessel owners and operators to maintain clean hulls. This could be achieved by DOC providing advance information that the consequence of failing the initial hull inspection will be a more detailed inspection and risk assessment of the vessel, which may take several days and still be associated with uncertainty about the outcome (a Coastal Permit may not be issued depending on inspection results). Therefore it will be in the vessel operators' interest to pass the initial hull inspection.

In the following section are suggested frameworks for:

- Determining which vessels require biofouling inspections, and what type of inspection;
- Determining the biosecurity risk of vessels on which biofouling organisms are detected; and
- Managing vessels that visit New Zealand's offshore islands regularly.

2.1 Which vessels require biosecurity inspections?

DOC's expectation is that vessels visiting the islands will have no visible biofouling on the hull. Only marine biofilm ("slime") is acceptable. Although this is difficult to achieve in practice, it represents a simple and clear standard that vessel operators can work towards. It is also consistent with the recent draft Import Health Standard developed by MAF Biosecurity New Zealand for biofouling on international vessels (MAFBNZ 2010).

DOC's current approach is to subject all vessels intending to land on the islands to an inspection, and it intends to require all vessels coming within 1000m of MHWS to meet the clean hull and niche area requirements also. However, there are situations where biofouling is unlikely to be present on a vessel and an inspection may not be necessary. The age of the antifouling paint on a vessel's hull is the best known predictor of biofouling extent and the presence of NIS (Coutts 1999; Floerl and Inglis 2005; Inglis et al 2010). Surfaces that have very recently received a new coating of antifouling paint will mostly be free of biofouling (AMOG Consulting 2002). Likewise, a vessel that has very recently received *comprehensive* in-water or shore-based cleaning may be clear of biofouling and pose no immediate biosecurity risk. During a recent MAF Biosecurity New Zealand funded research project, the hulls of approximately 500 international yachts, merchant vessels, passenger vessels and fishing vessels were sampled by divers upon the vessels' arrival to New Zealand (Inglis et al 2010; Piola and Conwell 2010). In this study, biofouling was not detected on some vessels that had received new antifouling paint in the 6 months prior to arrival to New Zealand. However, biofouling species were found on a considerable proportion of vessels that had been repainted $\leq$ 2 months prior to sampling (Table 1). In almost all cases, biofouling organisms encountered on these vessels were located in "niche areas" that were not coated in antifouling paint and/or were protected from hydrodynamic drag, such as propeller and rudder shafts. (See section 3.1 for details on niche areas).

We suggest that vessel operators that can provide evidence of a recent antifouling paint renewal or comprehensive biofouling removal should be exempted from a hull inspection. Meaningful criteria for deciding on a "safe" period are: (i) the time it takes for biofouling organisms to colonise non-toxic hull surfaces (as these are susceptible immediately a vessel enters the water) and (ii) the time it may take for biofouling organisms to reach sexual maturity (after which they may be able to release reproductive propagules into the surrounding environment). In a recent project for the Australian Department of Agriculture, Fisheries and Forestry (DAFF), NIWA determined biofouling accumulation rates to non-toxic substrates over time. Our review suggested that a range of biofouling taxa (e.g. bryozoans, barnacles, tubeworms, hydroids) can colonise a suitable surface within 1-2 weeks of submersion in the sea, although this timeframe is highly variable depending on latitude and season, and can take longer. Most species likely to be encountered on vessel hulls do not reach sexual maturity within 4 weeks of settlement. For example, the age at which the non-indigenous kelp *Undaria pinnatifida* has been reported to reach sexual maturity (measured as time from fertilisation of the female gametophyte to first release of zoospores from developed sporophyte) is 50 to 90 days (Thompson 2004; Primo et al 2010). More rapid maturation is achieved by tropical species in tropical or sub-tropical waters but these would be unlikely to survive in the cooler New Zealand waters.

Framework for biosecurity inspections

We recommend that all vessels, including privately owned craft such as yachts, are subject to a biofouling inspection unless they can demonstrate that their last antifouling paint renewal occurred *4 weeks or less* prior to the time they intend to visit New Zealand's offshore islands. Vessels antifouled within the previous 4 weeks should be exempt from an inspection because they are likely to be either free of biofouling or any organisms present are unlikely to have attained sexual maturity (Figure 1 - A). Vessels applying for an exemption must present appropriate documentation of their recent antifouling paint renewal. This could be in the form of a receipt and description of services from a maintenance operation.

The suggested framework incorporates two types of inspections for vessels that do not qualify for an exemption: (1) simple inspections for the presence of biofouling, and (2) comprehensive inspections to enable assessment of the biosecurity risk to the islands. The type of inspection required will be determined by whether or not the vessel operator can supply evidence that the vessel has recently (within the last 4 weeks) been inspected elsewhere and found to be free of biofouling or if it has been cleaned by an approved method, such as dry-docking or in-water cleaning. The framework would require DOC to develop a list of technical dive companies and hull maintenance facilities, in New Zealand and overseas, that it has "approved" to conduct biofouling inspections using the sampling protocols prescribed in this report and which are able to remove biofouling assemblages to a satisfactory standard. The acceptance of approved hull inspections and treatment if needed may provide incentives for pro-active maintenance measures to avoid delays that would be caused by more detailed inspections, a risk assessment and the need to obtain a Coastal Permit.

If a vessel has <u>not</u> undergone a hull inspection or approved cleaning activity within the 4 weeks of the intended date of travel to the islands, it will be required to undergo a comprehensive biofouling inspection (Figure 1 - C). This inspection must be carried out by an approved dive services provider using the sampling and specimen handling protocols described in Section 3. Sample handling, sorting and preservation, as well as all labelling need to be carried out by an approved scientific supervisor - not by the commercial dive company's surface support crew (unless they can be demonstrated to have scientific expertise). All samples need to be submitted to recognised taxonomic experts for identification and provision of biological and biogeographical information (Section 3). The inspection and identification process may take 2 days or longer and will involve costs that include consultancy fees and travel expenses of the scientific supervisor and fees for taxonomic identification of any samples collected (including freight of the samples). We suggest that identification of samples is carried out by NIWA's Marine Invasives Taxonomic Service (MITS[1]), whose taxonomic specialists provide species identifications for a range of ongoing marine biosecurity programmes and projects. We are able to provide an indicative price estimate on request.

In the event that the comprehensive inspection does not detect any biofouling, access to the coastal marine area of the islands should be allowed, provided any other requirements have been met. If biofouling is detected, samples will be collected using the methods described in Section 3 and will be identified by expert taxonomists. A risk assessment will be conducted on the results. Where the biosecurity risk is assessed as negligible, a Coastal Permit to visit the islands will be issued. If the risk is considered more than negligible the vessel operator will be required to arrange for treatment of the vessel before a Coastal Permit may be issued (Figure 1). The process for the risk assessment is described in Section 2.2 below.

If the vessel operator can provide evidence that an inspection or biofouling removal occurred <u>within 4 weeks</u> of the vessel's intended visit to New Zealand's offshore islands, the vessel operator should be given the choice of either undergoing the comprehensive biofouling inspection (as described above) or, a more basic inspection that only checks for the *presence* of biofouling on the vessel (Figure 1 - B). The inspection for presence of biofouling needs to be carried out by a DOC-approved dive service provider and follow the sampling protocols described in this report (Section 3). If no biofouling is detected during this inspection, biosecurity risk is deemed negligible and close inshore access to the coastal marine area of the islands should be allowed (no coastal permit required) (Figure 1). Basic inspections for biofouling presence do not require a scientific supervisor to be on site as no samples are collected. This reduces the costs of the inspection. However, if biofouling is encountered during the inspection, the vessel fails the inspection and is presented with two options: either biofouling assemblages are removed using an appropriate treatment method or the vessel undergoes the comprehensive biofouling inspection and risk assessment described in the paragraphs above (Figure 1). In the latter situation, the vessel operator would incur the costs of *two* inspections plus the costs for science staff and taxonomic identification associated with the second (detailed) inspection. It may also be required to undergo treatment if the biosecurity risk is assessed to be non-negligible. It is the vessel operator's responsibility to decide on whether to

[1] MITS is an initiative funded by MAF Biosecurity New Zealand, with provisions to carry out taxonomic consultancy for other agencies. The Service operates under high quality standards and was established to provide species identifications and associated biogeographic information with rapid turnaround.

opt for the simple, cheaper inspection or the second, comprehensive inspection. The simple inspection is faster and cheaper, but would represent a saving only for vessels on which no biofouling is detected.

The decision framework described above is designed around DOC’s preferred standard of an absence of biofouling on vessels intending to visit the offshore islands. It enables vessel operators to undertake self-assessment based on DOC’s expectations and, if required, to take pro-active measures to ensure that their vessel meets DOC’s expectations. It also exempts vessels that have very recently received a new antifouling coating from the requirement of an inspection.

Table 1: Incidence of biofouling presence and average number of species on vessels with antifouling paint of different ages. Data were collected from international yachts, passenger and fishing vessels sampled upon arrival at New Zealand customs ports in 2005-07 for MAF Biosecurity New Zealand research projects ZBS2004-03 and ZBS2004-4. We acknowledge MAFBNZ's friendly permission to reproduce this data here.

	Passenger vessels (N=50)			**Yachts (N=146)**			**Fishing vessels (N=11)**		
AFP age (months)	**N**	**% fouled**	**Avg. no. sp.**	**N**	**% fouled**	**Avg. no. sp.**	**N**	**% fouled**	**Avg. no. sp.**
0-1	2	50	4	3	67	6	1	0	
1-2	7	14	8	6	17	4			
2-3	6	0		4	50	10			
3-4	4	50	2	5	100	3	1	0	
4-5	1	100	1	11	55	5	1	0	
5-6	1	0		11	73	3			
6-7	2	100	1.5	11	64	4			
7-8	1	0		16	88	5			
8-9	2	50	2	9	100	5	1	100	8
9-10	3	67	1.5	7	86	3	2	100	9.5
10-11	2	100	1.5	6	100	3			
11-12				7	86	4	1	100	5
12-13	2	50	3	12	100	5			
13-14				6	100	6			
14-15	3	100	7	1	100	2			
15-16	3	67	3.5	2	100	6			
16-17				5	100	5			
17-18				3	100	7			
18-19				3	100	4	1	100	3
19-20				3	100	7	1	100	2
20-21	3	67	3	1	100	4			
21-22	2	100	6	2	100	7			
22-23				1	100	4			
23-24									
24-25				1	0				

AFP age (months)	Passenger vessels (N=50)			Yachts (N=146)			Fishing vessels (N=11)		
	N	% fouled	Avg. no. sp.	N	% fouled	Avg. no. sp.	N	% fouled	Avg. no. sp.
25-26	1	0							
26-27				1	0				
27-28	2	100	1.5	2	100	7			
28-29									
29-30	1	100	15	1	100	12			
30-31	1	100	5				1	100	20
31-32				2	100	8			
32-33	1	100	1						
33-34									
34-35									
36-37									
38-39							1	100	3

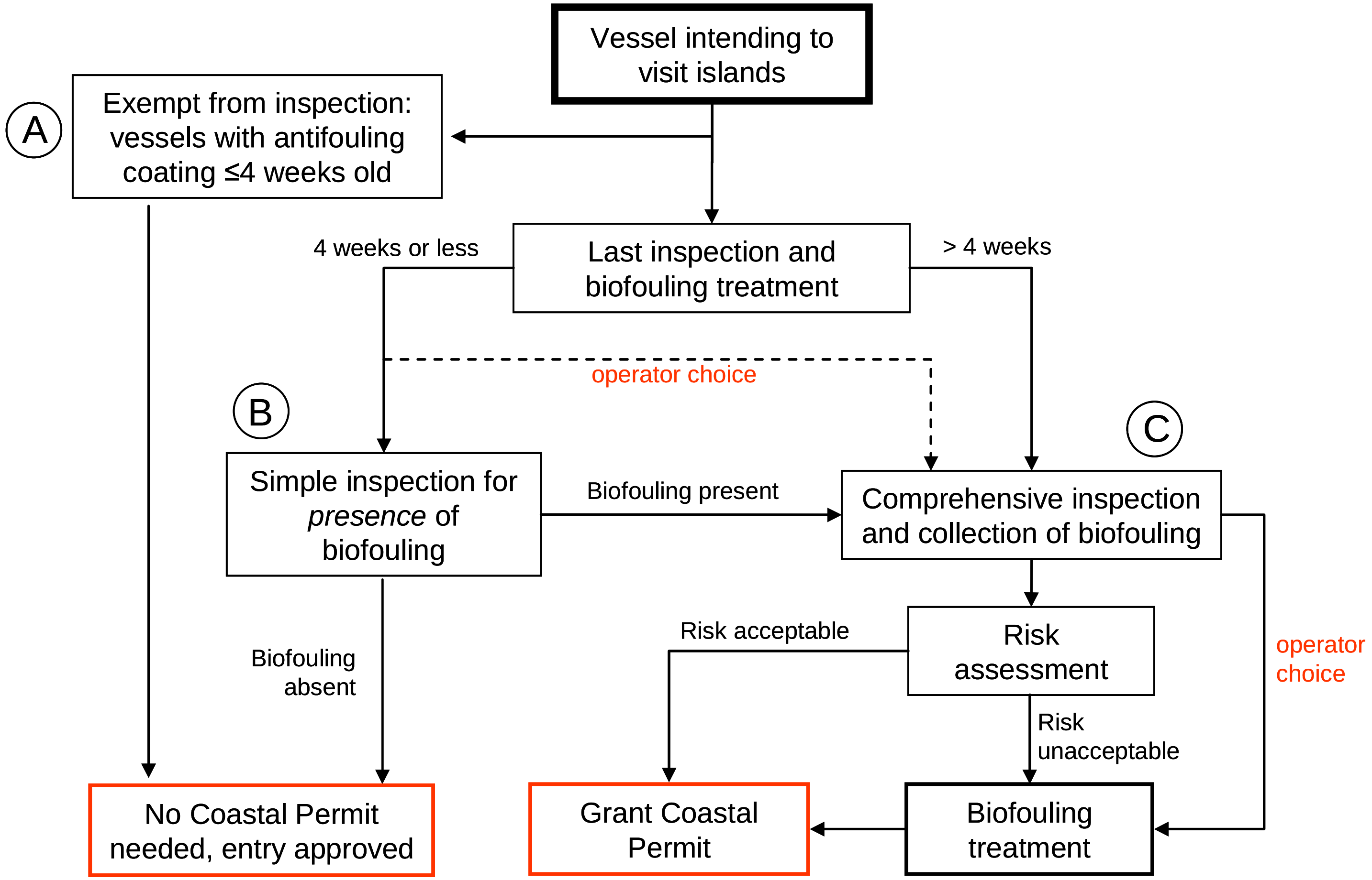

Figure 1: Decision framework for the requirement for vessel biofouling inspections. Simple (biofouling presence/absence) inspections or comprehensive inspections (biofouling collection and risk assessment) are required depending on the maintenance history the vessel is able to document evidence for. Situations A, B and C correspond to descriptions in the main text.

2.2 Risk assessment of vessels based on inspection and taxonomic results

Section 2.1 described a suggested framework for determining whether a biofouling inspection is required and what type of inspection may be appropriate.

When a comprehensive inspection results in the detection of biofouling, vessel operators should have the choice of either arranging for removal of the biofouling from the vessel using an approved methodology, or undergoing a biofouling risk assessment (Figure 1). In this section, we describe the method proposed for assessing the biosecurity risk a vessel is likely to pose to New Zealand's offshore islands based on the identity and abundance of species discovered on its hull. We define biosecurity risk as the ability of a species to become established and survive in the islands. The risk assessment framework is based on four factors: (1) whether or not NIS are present on a vessel, (2) the likelihood of these NIS establishing and surviving in the sub-Antarctic or Kermadec islands, (3) whether any of the NIS have a history of invasion in other global regions, and (4) the extent of biofouling on the vessel. We evaluate risk using a simple ordinal scale: negligible, low, medium, high or very high. These levels represent <u>relative</u> estimates of biosecurity risk. They are not be interpreted as <u>absolute</u> measures of biosecurity risk or as estimates of the likelihood for the establishment and/or impacts of biofouling species in New Zealand's offshore islands.

Risk factor 1: Presence of non-indigenous species

If the biofouling species detected on a vessel are indigenous to the proposed destinations of the vessel they pose no risk to these environments. For example, the stalked barnacle *Lepas anatifera* is a cosmopolitan species that is frequently encountered on vessel hulls. It occurs around New Zealand's North and South Islands as well as the sub-Antarctic and Kermadec Islands. Vessels carrying exclusively species that are native to the intended destination are considered to pose a negligible biosecurity risk (Table 2).

Risk factor 2: Ability to establish and survive

If one or several species on a vessel are non-indigenous to the islands the level of biosecurity risk attributed depends on whether the species could survive and establish viable populations there. For example, tropical species "picked up" by the vessel during time in low-latitude environments are unlikely to survive in sub-Antarctic waters. A recent example of this was a number of species detected on the hull of the cruise vessel *Clipper Odyssey*, which were deemed unable to survive in the coastal sub-Antarctic waters (Floerl et al. 2009). If the taxonomic specialist conducting the identification determines that a species is not indigenous to the offshore islands but is unlikely to survive in these environments, a low biosecurity risk is attributed to this species. Vessels on which NIS are detected that could possibly or likely become established in the vessel's intended destinations, are attributed a medium to very high biosecurity risk depending on the invasion history of the species and the overall extent of biofouling on the inspected vessel (see below and Table 2)

Factor 3: Invasive history

The framework includes three levels (or categories) of invasion history: (i) no global record of establishment outside native range; (ii) documented establishment outside the native range (no reports of ecological and/or economic impact), and (iii) documented invasion with associated ecological and/or economic impact. The presence of an invasive history is not *always* a reliable predictor of risk, as the likelihood of establishment and spread of a NIS is dependent on a wide range of biotic and abiotic factors associated with the recipient environment (Simberloff and Gibbons 2004). However, as a precautionary measure, the highest level of biosecurity risk is attributed to vessels carrying NIS that are considered to be able to survive in the sub-Antarctic or Kermadec islands *and* that are known to have an invasive history in other parts of the world (Table 2). This automatically includes any species declared as Unwanted Organisms under New Zealand's Biosecurity Act (1993).

Factor 4: Extent of biofouling on the vessel

The number of individuals or colonies of a NIS that are present on a vessel determines the number of reproductive propagules or other life-history stages that may be released in a new environment. For example, the presence of a single individual of a dioecious species (a species in which gametes are separate sexes) may represent a negligible biosecurity risk. A larger number of individuals (or colonies) may translate into higher risk as more individuals can release a larger number of reproductive propagules or, in the case of mobile species such as small crustaceans, more individuals can potentially leave the vessel and sink or swim into the local environment. In general terms, if more *species* arrive in an environment there is a greater chance that some will be suited to this environment. Similarly, if more *individuals* arrive there is a greater chance that the population will overcome demographic and environmental stochasticity and Allee Effects [2] to become established (Mack et al. 2000; Lockwood et al. 2005).

For reasons of efficiency and cost, the biofouling inspections described in this report do not quantify the abundance of individual species on a vessel. However, the Level of Fouling (LOF) ranks provide a measure of the extent and abundance of biofouling across the hull. In our evaluation of risk, a higher level of biosecurity risk has been attributed to vessels where the LOF rank allocated to any of the locations from which the NIS were collected was 4 or 5 (i.e. high to very high biofouling abundance, covering 40–100 % of a targeted surface) than to vessels where this LOF was 2 or 3 (low to moderate, patchy biofouling covering 1–16 % of a targeted surface; Appendix 1). While this is a simplistic approach to quantifying the amount of

[2] Environmental stochastity refers to random environmental factors such as temperature, space or food availability. Allee effects are a biological phenomenon in which there is a positive correlation between population density and the per capita population growth rate in very small populations.

biofouling it does ensure that species collected from hull locations with a high abundance of biofouling are treated with a high degree of caution.

Table 2 presents all possible combinations of the risk factors described above. In summary:

(i) vessels that carry biofouling consisting entirely of indigenous species present a negligible biosecurity risk to the sub-Antarctic and/or Kermadec islands, and

(ii) vessels that carry NIS that are unlikely to survive in the vessels' intended destinations (e.g. tropical species where the destination is the sub-Antarctic Islands) present a low biosecurity risk to the sub-Antarctic and/or Kermadec islands, and

(iii) vessels with NIS that are thought to be able to survive in the vessels' intended destinations are attributed a medium, high or very high biosecurity risk depending on whether they are known to be invasive elsewhere in the world and the extent of biofouling on the vessel in question (Table 2).

Table 2: Evaluation of the biosecurity risk vessels intending to visit New Zealand's remote offshore islands pose to their intended destinations. Levels of biosecurity risk are simple relative estimates based on (i) whether NIS are present on a vessel, (ii) how likely they are to establish in the vessels' intended destinations, (iii) whether they are known to have a history of invasion in other global locations, and (iv) the extent of biofouling on the vessel. The risk estimate is made for the entire vessel and on criteria i-iv for all species detected on the vessel.

NIS present on vessel?	Likelihood of establishment in offshore islands?	Invasive history of NIS found on vessel	Max. LOF of hull areas NIS was collected from	Relative biosecurity risk
No	n/a	n/a	2 to 3	Negligible
No	n/a	n/a	4 to 5	Negligible
Yes	Unlikely	No record	2 to 3	Low
Yes	Unlikely	No record	4 to 5	Low
Yes	Unlikely	Record of establishment	2 to 3	Low
Yes	Unlikely	Record of establishment	4 to 5	Low
Yes	Unlikely	Record of invasion	2 to 3	Low
Yes	Unlikely	Record of invasion	4 to 5	Low
Yes	Possible	No record	2 to 3	Medium
Yes	Possible	No record	4 to 5	High
Yes	Possible	Record of establishment	2 to 3	High
Yes	Possible	Record of establishment	4 to 5	Very High
Yes	Possible	Record of invasion	2 to 3	Very High
Yes	Possible	Record of invasion	4 to 5	Very High
Yes	Likely	No record	2 to 3	High
Yes	Likely	No record	4 to 5	Very High
Yes	Likely	Record of establishment	2 to 3	Very High
Yes	Likely	Record of establishment	4 to 5	Very High
Yes	Likely	Record of invasion	2 to 3	Very High
Yes	Likely	Record of invasion	4 to 5	Very High

Management of vessels that are non-compliant

This section contains recommendations on how the level of risk resulting from the assessment described in the paragraphs above and Table 2 might be used for the permitting process. However, it is DOC's responsibility to determine, based on the results of inspection and risk assessment for individual vessels, whether a Coastal Permit will be issued.

It is suggested that all vessels attributed with a negligible or low biosecurity risk may be issued Coastal Permits. These vessels very likely either do not contain NIS or only species that are unable to survive and establish in the target destinations.

Vessels attributed with a biosecurity risk higher than "low" should not be allowed to travel to New Zealand's offshore islands unless the biofouling assemblages have been removed. Feasible treatment options include: (1) removal of the vessel from the water in a dry-dock or haul-out facility and cleaning of all biofouling using high-pressure water blasting, (2) wrapping of the entire hull in a non-permeable barrier ("encapsulation") and treatment with fresh water or an appropriate chemical, or (3) in-water cleaning using a method that is able to capture biogenic and inorganic waste for disposal to land fill. The method used for treating and/or removing biofouling from a vessel hull may need to be based on the extent of biofouling present on the vessel. Spot cleaning of isolated patches of biofouling may be feasible for vessels where the biofouling is not extensive. However, different approaches may be required for vessels with more extensive biofouling assemblages on their hulls. Further comments and suggestions regarding in-water cleaning are presented in the sections below.

For a discussion of risk factors excluded from our evaluation of biosecurity risk see Appendix 2.

2.3 Suggested framework for vessels undergoing repeated seasonal travel to the islands

Some vessels, such as New Zealand-based fishing vessels and a range of cruise ships, operate around the Kermadec and/or sub-Antarctic islands on a seasonal basis. They may make repeated voyages to the offshore islands, with intermittent return to a New Zealand mainland port to change crews or passengers and/or to load or unload supplies or catch. In 2009, for example, the vessel *Spirit of Enderby* (Natural Heritage Expeditions) travelled to New Zealand's sub-Antarctic islands on at least three different occasions. Visits to mainland ports (in this case Bluff) generally lasted 24-72 hours. Under the current regime followed by DOC, the vessel was required to undergo a biofouling inspection before each consecutive trip.

Several factors suggest that a slightly different management framework should be used for vessels that undergo frequent or seasonal travel to New Zealand's offshore islands. If successive voyages to the islands are preceded by short (1-3 days) residencies in New Zealand ports, the likelihood of becoming colonised by biofouling organisms during these residencies may be small and not warrant the costs and delays associated with comprehensive inspections, for two reasons. First, the likelihood that biofouling organisms will recruit to a vessel's hull during short residencies is unknown and varies between seasons (Richmond and Seed 1991). Second, biofouling developing on the hulls of such vessels may also originate from the vessel's offshore island destinations and pose no biosecurity risk. In the case of vessels passing through locations associated with sea ice, scouring may also remove biofouling organisms from hull areas that come into contact with the ice (Lee and Chown 2009). However, sea ice is not likely to affect niche area biofouling and any damage the ice causes to the vessel's antifouling paint may increase the susceptibility of affected hull areas to colonisation by biofouling.

Management of vessels that frequently or seasonally travel to the offshore islands should involve an initial simple or comprehensive inspection prior to their first visit of the season following the descriptions in Section 2.1. Once the vessels meet DOC's expectations and receive permission to travel to the offshore islands, several options are available for managing the risks associated with subsequent seasonal voyages.

One option is to subject such vessels to periodic *target inspections* for specific NIS that are known to be established in the New Zealand ports the vessels visit between voyages and that pose a biosecurity risk to the offshore islands. The timing of these targeted surveys should be determined by the species' reproductive seasonality. Target inspections can be carried out cost- and time-effectively by technical dive teams trained in the identification of the target species. However, this approach has a number of disadvantages. One is that such a system is species-focused and ignores the potential risks posed by non-target non-indigenous species. Another disadvantage is that the presence or absence of high-risk marine pest species in New Zealand ports can only be ascertained by periodic target surveys within these ports. The ongoing, MAF Biosecurity New Zealand funded nationwide target surveillance programme is restricted to key locations that do not include all ports from which vessels depart to the offshore islands (e.g. Gisborne, Timaru, etc.). As such the utility of target surveillance may be restricted.

A second option would be for DOC to require periodic *simple* biofouling inspections for vessels that undergo seasonal or repeated travel to the offshore islands. Under such a regime, the vessels would not be required to undergo an inspection prior to each consecutive voyage to the offshore islands, provided they have only very short residencies in a New Zealand port. Instead, repeat inspections would be required according to an agreed schedule. Repeat inspections on vessels undergoing regular or seasonal travel to New Zealand's offshore islands should be treated as an adaptive process. Initially this could involve more conservative intervals between inspections. During each sampling event, inspectors should monitor and document the development of biofouling assemblages on these vessels by using photographs and LOF ranks. Data collected through this monitoring can then be used to optimise the periods between repeat surveys and achieve the best balance between risk reduction and avoiding excessive costs for seasonal operators.

2.4 Issues for consideration

Options for treatment of biofouling

An important issue for the success of the assessment framework is the availability of appropriate treatment facilities for vessels that are non-compliant with the biofouling standard. Currently, no biofouling treatment options are readily available to vessels that fail biofouling inspections required by DOC. This is a problem particularly for commercial vessels on a tight schedule. The Code of Practice for Antifouling, Maintenance and In-Water Cleaning released by the Australia and New Zealand Environment and Conservation Council in 1997 (ANZECC 1997) prohibits in-water cleaning of vessels based on a dual concern over the release of toxic antifouling paint material and non-indigenous organisms into the local environment. While the ANZECC Code has not been officially adopted in New Zealand, regional councils and unitary authorities with jurisdiction for marine areas generally prohibit in-water cleaning for the same reasons as in the ANZECC Code, through rules in plans developed under the Resource Management Act. The requirement to remove biofouling prior to travel to the islands may not be a significant issue for recreational vessels and small fishing vessels, which can be removed from the water for cleaning relatively easily, in a range of facilities around the country. However, it is a constraint for larger fishing vessels or cruise vessels that require cleaning. New Zealand has only two dry-docks, which are in high demand and unable to accommodate urgent short-term bookings. For many vessels (i.e. fishing and cruise vessels), travel to distant dry-docks and associated waiting periods will cause unacceptable delays and significant costs.

A range of effective in-water cleaning or biofouling treatment technologies is currently available or being developed. These include technologies with mechanisms to capture biofouling organisms removed from hull surfaces to prevent the unwanted release of potentially live biological material. The ANZECC Code is currently being revised and may allow the use of some effective and low-risk technologies for in-water cleaning of vessels. However, until the ANZECC Code is revised, larger vessels that require treatment of biofouling may not be able to access suitable facilities within New Zealand. Local authority regional coastal plans prepared under the Resource Management Act are likely to require resource consent to clean a vessel in water. The process of applying for resource consent can take up to several weeks and would cause an unacceptable delay for cruise ships carrying paying passengers. To overcome these hurdles, we suggest that shipping companies, vessel operators, regional councils and DOC work together to identify and pursue options that provide vessels undergoing inspections with options for biofouling treatment, if required. This may involve the development of Permitted Activities or rapidly approved resource consents for particular treatment methods undertaken by approved providers while the vessel remains in the port.

Undertaking inspections; training in LOF rank allocation

The comprehensive biofouling inspections outlined in Section 2.1 should be carried out by a team of technical divers trained in the sampling methods, and supported by a scientific supervisor who handles and manages labelling, processing (sorting and preservation) and dispatch of samples to taxonomic experts via MITS. Diving under large vessels is a hazardous activity and should only be carried out by appropriately trained personnel. It is important, however, that the technical divers are also proficient in collecting biological samples, recording accurate information and in taking high-quality underwater images of the various hull locations inspected. The LOF ranks will be used as a surrogate for biofouling extent and it is important that the ranks are assessed correctly. Photographic images should be used to support taxonomic identification and may also be used by the scientific supervisor to assess LOF ranks. We recommend that DOC identify a list of approved dive service providers to receive training in inspection protocols.

Sea chests

Sea chests are cavities recessed into the hull of a vessel. They house the intakes for ballast water and cooling water, and are covered by gratings set flush against the hull. There can be 2-8 sea chests on a vessel and these structures have been shown to harbour extensive assemblages of biofouling organisms as well as mobile species (crabs, fishes, etc.) (Coutts and Dodgshun 2007). The inspection and risk assessment framework for biofouling on vessels travelling to

New Zealand's offshore islands presented in this report does not address the biosecurity risks posed by sea chests. Divers are able to examine the gratings of sea chests during an inspection, but cannot usually inspect the inside of the sea chests unless the gratings are removed. A variety of species can occur inside vessels' sea chests. The absence of NIS on external hull surfaces, therefore, does not guarantee that they will not be present in internal recesses such as sea chests.

Working with industry to manage biofouling

Development and implementation of the risk assessment and management framework discussed in this report will be most effective if they are done in consultation with affected parties. It is recommended that DOC work with representatives of the cruise ship, fishing, yachting and technical diving industries to determine the practicality of the framework, and options for adapting it (if required and appropriate) to best integrate with the requirements, restrictions and operations of all affected industries.

Dissemination of relevant information

Once the management framework has been finalised, it is important that all aspects of it remain transparent and that it is easily accessible to vessel operators. These include (at least) the cruise ship and fishing industries, yachting associations and other industries that require vessel access to New Zealand's offshore islands. Easy access to resources such as DOC's expectations regarding hull hygiene, the decision frameworks, inspection details and relevant forms will enable prospective visitors to take pro-active steps. It is important that vessel operators are able to access information on treatment or mitigation options for biofouling on vessels that fail the inspections and risks assessment.

3. Templates for inspections and risk assessment

This section contains a collection of protocols and resources that will enable a contractor to conduct biofouling inspections on vessels wanting to access the coastal marine area of the islands within 1000m of MHWS. It details how to collect the information that is required by DOC to determine if access can be allowed as a permitted activity (i.e. no coastal permit required); whether a risk assessment and coastal permit are required, or whether access will be prohibited. The following information is included below:

(a) Protocols for standardised inspections of vessel hulls for biofouling (both the simple and the comprehensive inspections),

(b) Protocols for handling, labelling, and preserving samples of biofouling and their dispatch to taxonomic specialists,

(c) Species-specific information required from the taxonomists to inform the risk assessment, and

(d) A summary template for submission to DOC in which the contractor describes the results of the biofouling inspection. DOC can then use this information to determine whether a Coastal Permit will be granted.

3.1. Protocols for standardised biofouling inspections on vessel hulls

Background to biofouling on vessel hulls

Biofouling is the colonization of a vessel’s submerged surfaces by marine invertebrates and plants. Biofouling will occur on any surface that is not protected by a layer of functional toxic “antifouling paint” or where this paint is old and ineffectual.

The submerged hull area of a vessel can range from <100 m^2 (yachts) to several thousand m^2 (large cruise ships). Biofouling is generally not evenly distributed across a vessel’s hull but is concentrated in areas that are not coated in antifouling paint and/or that are protected from strong water flow when the vessel is moving. These locations are commonly referred to as ‘niche areas’ and include the rudder recess, propeller shaft, bow thrusters, gratings, and others (more detail in sections below and Figure 3). Depending on vessel type, niche areas may contain > 75 % of the fouling biomass and richness (number of species) present on a hull (Inglis et al 2010). Biofouling can also occur on general hull areas, especially on slow-moving vessels and in hull locations protected from hydrodynamic drag. Because biofouling is generally patchily distributed across a vessel's submerged surface area, the most efficient sampling approach (i.e. one that maximizes the proportion of species detected for a given level of effort) is a stratified design that pays particular attention to high-risk niche areas, where most biofouling tends to occur.

A. Comprehensive hull inspections

This section describes the protocols for conducting a comprehensive biofouling inspection as described in Section 2.1.

Objectives of a vessel biofouling inspection

The sections below describe hull sampling protocols that target both general hull locations and niche areas. The overall objective of the inspection described is to detect the majority of biofouling species occurring on a vessel's hull. The inspection cannot guarantee an absence of biofouling as it has not been designed using a statistical framework that will provide a level of confidence of "freedom of infestation". The inspection is not intended to estimate the abundance of individual species on the vessel (e.g. biomass, or numbers of individuals). However, it does provide a quantitative estimate of the extent of biofouling. The protocols described here use a Level of Fouling (LOF) index to quantify biofouling. The use of the index is described in Appendix 1.

Requirements

Staff and equipment

The diving operation is best carried out by a team of at least two divers (SCUBA or surface-supplied diving) supported by a topside crew, ideally in a small vessel. The use of two divers is recommended for safety, makes it easier and more efficient to carry out the various tasks (e.g. photography, sample collection, bagging and labeling) and enhances quality assurance. Divers should be equipped with dive lights, dive knives and, ideally, a means of communication with topside personnel. Full-face AGA masks with inbuilt microphones are best suited for this.

Essential sampling equipment for the divers includes:

- Paint scrapers (or similar) to remove biofouling from the hull. Plastic scrapers are best as metal scrapers are more likely to damage the hull surface. If care is taken during sample collection, damage to the antifouling paint film on the hull will be avoided. Firmly encrusting or cementing organisms such as large barnacles and oysters may need to be removed using a dive knife.

- Sample collection bags. Fine mesh bags (500 µm) with a pull-cord for closing are best. Zip-lock or other plastic bags are unsuitable as they do not allow water to pass through and result in the loss of sample material when the bag is being filled and closed. If only plastic bags are available, puncturing 10-20 *fine* holes in them using a needle is a useful method to avoid loss of sample material.

- A sampling quadrat. A size of 20 x 20 cm (0.04 m^2) is suitable for underwater work. The size of the quadrat needs to be indicated on the field sheets. When working on vessels with steel hulls, it is useful to attach a small magnet to each corner of the quadrat so it can be attached to the hull during sampling.

- A set of pre-printed sample labels (waterproof paper) that correspond to the sampling locations around the hull. Labels need to be displayed in all digital images and be included with any biofouling samples collected. See section 2.2 for more detailed instructions on labelling. For steel hulled vessels it is useful to have a magnetic clip that can fix a label to the hull surface while it is being photographed.

- A digital underwater camera for taking close-up images of biofouling assemblages. The camera should be equipped with an adequate strobe positioned in a way that minimises over- or underexposure of the image and back-scatter.

Essential knowledge and training

Divers and surface personnel undertaking biofouling inspections need to be competent in a variety of tasks to undertake a thorough inspection following the protocols described here. Required are:

- Current OSH certification, medical clearance and commercial diving certificate (divers).

- Competence in the use of the LOF rank index (divers and surface personnel).

- Familiarity with all hull sampling locations, the sampling plan and the way information is captured on sample labels (divers and surface personnel).

- Some knowledge of common biofouling organisms to ensure that all or most species are sampled, to avoid damaging fragile organisms during removal from the hull and to ensure efficient sorting and sample processing (divers and surface personnel).

Below is a list of the basic requirements for health and safety at the site of a vessel biofouling inspection.

- The vessel's engines need to be fully shut down, including thrusters.

- The Port Authority or Harbour Master should be notified of the diving activity to warn any other vessels operating in the vicinity of the presence of divers in the water. Topside personnel need to fly a dive flag while the hull inspection is underway.

- First Aid and O_2 resuscitation equipment need to be at the dive site and team members need to be trained in administering first aid to divers and non-divers.

- The dive should be carefully planned by the dive supervisor in accordance with recognized dive tables (e.g. Bühlmann, PADI, etc.). Depending on the length and draft of the vessel, rotation of divers might be required to ensure safety and prevent fatigue. The tide should be taken into consideration when planning the dive. Areas like the keel bottom are important to inspect, but may not be safe to access during a falling tide in a shallow environment.

- A dive plan should be developed in advance of the inspection that identifies any risks associated with the inspection and a strategy for risk management and response to emergencies.

Sampling protocols

During a vessel inspection, divers will examine general hull areas and niche areas occurring around the vessel. Ideally, a plan of the ship should be consulted prior to the inspection to identify areas on the hull that need to be targeted and their exact location.

Use of digital photographs

In some instances, the taxonomic identification of biofouling samples is made easier when digital images of the organisms are taken before the organisms are removed from the hull. Images can also be used to verify LOF ranks following an inspection. The divers should carry an underwater camera with a suitable strobe. A digital image should be taken of biofouling organisms *in situ* before they are collected. In each image, a slate should be visible that identifies the location (e.g. rudder, keel, hull, etc.) of the image. The image should be taken at a distance of approximately 30 cm from the hull surface to ensure organisms are visible in sufficient detail. A distance rod can be attached to the camera to ensure a constant distance. Lower distances may need to be used in sampling locations with poor visibility.

1. Sampling of general hull areas

Previous vessel surveys have shown that the biofouling in general hull areas most often occurs in two locations: (i) close to the waterline, where antifouling paint is often damaged during berthing operations or by striking floating debris while sailing, and (ii) in the stern area of the vessel, where hydrodynamic drag is reduced when a vessel moves through the water (ASA 2007; Inglis et al. 2010). General hull areas should therefore be sampled by vertical stern transects and by horizontal transects along the entire waterline of the vessel.

Vertical stern transect

Separate vertical transects should be conducted on the port and starboard sides of the vessel at the stern. These are best situated ~5m from the stern, where the hull curves inwards (Figure 2). When surveying the transects, the divers slowly descend from the waterline to the deepest part of the hull (keel bottom) and look for biofouling. The width of observation should be approximately 1 m. In low-visibility environments two divers may need to swim side-by-side and cover a width of 0.5 m each. A LOF rank should be allocated to each transect on the basis of the amount and diversity of biofouling encountered (see Appendix 1 on how to allocate LOF ranks). Representative digital images should be taken of biofouling organisms present in each transect to provide a permanent record. Images should be taken at a constant distance of approximately 30 cm from the hull surface. Each image should contain a slate or label identifying the location it was taken in (e.g. stern transect, on port side).

The method of collection of biofouling samples depends on the LOF rank allocated:

- For transects with LOF ranks of 2 (light fouling) and 3 (moderate fouling), representative samples of all biofouling species are collected by the divers along the transect. Where available, at least three (3) individuals or colonies of each distinguishable species should be collected for identification purposes. Images of the organisms should be taken prior to removal, and each image needs to contain a slate or label that identifies the location in which it was taken.

  All material collected during the transect is placed into the same sample bag for simplicity, along with a waterproof label that identifies:

  - vessel name and date;
  - side of vessel (port, starboard);
  - transect type (i.e. Stern vertical transect);

- LOF rank.

- For transects with LOF ranks of 4 (extensive fouling) and 5 (very heavy fouling) it is too difficult for the divers to reliably "seek out" all of the species present. Instead, the divers place a sampling quadrat into each of five (5) haphazardly selected locations along the transect. The quadrats can be placed anywhere within the 1-m width of the transect. A digital image of each quadrat is taken prior to removal of the organisms, and each image needs to contain a slate or label that identifies the location it was taken in. Using a paint scraper, the entire contents of each quadrat are then transferred into a separate sample bag, along with a waterproof label that identifies:

    - vessel name and date;
    - side of vessel (port, starboard);
    - transect type (i.e. Stern vertical transect);
    - LOF rank;
    - Quadrat number (1-5).

If more than a single sample bag is required, an identical label is placed into the second (third, etc.) bag such that samples taken from the same transect can be processed together following the inspection.

In summary: two vertical transects are inspected at the stern: one on the port and one on the starboard side. Each transect receives a LOF rank, has representative images taken of any organisms encountered and representative samples (LOF ranks 2 and 3) or quadrat samples are taken of biofouling (LOF ranks 4 and 5).

Horizontal waterline transect

During the horizontal waterline transect the divers inspect the hull from the waterline to approximately 1 m below the waterline along the entire length of the vessel on both port and starboard sides. Biofouling is particularly likely to occur in areas where the antifouling paint is damaged as a result of abrasion during docking operations or where the vessel has struck floating debris (ASA 2007). The waterline transect is divided into three parts:

1. Waterline (stern),
2. Waterline (amidships), and
3. Waterline (bow).

Each of these segments is allocated a separate LOF. Digital images should be taken and biofouling samples should be collected as described above for the vertical stern transect: representative specimens collected for LOF ranks of 2-3, or three replicate sample quadrats where the LOF is 4 or 5.

2. Sampling of niche areas

Most biofouling on most vessels is located within niche areas. The most common niche areas on vessel hulls are listed below. The codes in brackets represent abbreviations that can be used for sample labels. Niche areas marked by an asterisk (*) are likely to be present on both port and starboard sides of a vessel, in which case both need to be inspected.

- rudder and rudder shaft/recess [RS];
- propeller and propeller shaft* [PS];
- anodes* (often several along hull) [AN];
- dry-docking support strips (areas along keel bottom on which the vessel rests while in dry-dock, thus lack antifouling paint [DS];
- sea chest gratings* [GR];
- openings of intake or outflow pipes* [OP];
- bilge keel* [BK];
- bow thrusters* [BT];
- areas of damaged paint surface* [DP].

An illustration of a vessel's niche areas is given in Figure 3. Not all of these niche areas will be present on each inspected vessel, but each of those present needs to be targeted during the inspection. Each niche area should be inspected in its entirety and be allocated with a LOF rank on the basis of the amount and diversity of biofouling present in the entire niche area. One or several digital images should be taken of each niche area prior to removing any biofouling, and in each image a slate should be visible identifying the location it was taken in (e.g. BT, DS, etc.).

The method of collection of biofouling from niche areas depends on the LOF rank allocated:

- For niche areas with a LOF rank of 2 (light fouling) or 3 (moderate fouling), representative samples of all biofouling species are collected by the divers. Ideally, at least three (3) individuals or colonies of each distinguishable species should be collected for identification purposes.

  All material collected from a given niche area is placed into a single sample bag, along with a waterproof label that identifies:

- vessel name and date;
- side of vessel (port, starboard);
- type of niche area;
- LOF rank.

If more than one sample bag is required, an identical label should be placed into the second (third, etc.) bag.

- For niche areas with a LOF rank of 4 (extensive fouling) or 5 (very heavy fouling) it is too difficult for the divers to reliably "seek out" all of the species present. Instead, an alternative collection method is used that depends on the size of the niche area.

  If the niche area is relatively small (e.g. intake/outflow openings; damaged paint areas, etc.), the divers should collect all of the biofouling present in the niche area and place it into a single sample bag containing a waterproof label that identifies:

  - vessel name and date;
  - side of vessel (port, starboard);
  - type of niche area;
  - LOF rank.

  If the niche area is large (e.g. rudder, DDSS, propeller, etc.) then the divers should take a quadrat sample in each of three (3) haphazardly selected locations within the niche area and transfer the entire contents of each quadrat into a separate sample bag, along with a waterproof label that identifies:

  - vessel name and date;
  - side of vessel (port, starboard);
  - type of niche area;
  - LOF rank.
  - Quadrat number (1-3).

Some niche areas may occur more than once on a vessel, particularly sea chest gratings (usually 2-8 depending on vessel size) and dry-docking support strips (potentially >10). The divers should target all of these where possible.

3. Opportunistic samples

If the divers encounter biofouling outside the hull transects and niche areas listed above, images should be taken and representative samples should be collected using an appropriate label.

4. Sample handling and recording

Biofouling organisms sampled from the vessel hull must be removed gently using (preferably) a plastic paint scraper. When removing biofouling from a hull area the divers should attempt to minimise damage to fragile organisms. Accurate species identification relies on detailed examination of the organism's morphology and, often, external features. Specimens may not be able to be identified if damaged or broken (i.e. crushed barnacle shells, torn/crushed algae, squashed crustaceans). Care must also be taken to prevent damage to the vessel's hull surfaces and structures. This includes sites where sessile organisms (such as barnacles, sponges or ascidians) are scraped off. Although likely to be minimal, care must be taken to avoid removing paint during hull scrapings.

The divers should ensure that all material removed from a hull is transferred into the sample bags and that no organisms are lost and able to sink to the seafloor below the vessel. Non-indigenous species escaping into the local environment may pose a biosecurity risk to the location of the inspection and the release of any biofouling or antifouling paint material from the vessel may require a resource consent from the regional council (or unitary council). It is important that samples are placed into sample bags containing the correct label to ensure species identifications from specific areas on the ship are accurate.

Field data recording sheets should be developed and used during the inspection that allow the topside personnel to log the hull and niche areas inspected by the divers, the LOF allocated to each inspected area and whether and where any samples were collected (and using which methods) and/or images taken. Such field sheets also provide a measure of quality assurance to ensure that all hull areas are sampled.

Following collection, the samples need to be transferred to a field laboratory for sorting and preservation. To make an inspection most efficient, transfer of samples should occur as soon as these have been received from the divers. It is important to check that each sample contains a correctly completed label and that a sample register is developed that identifies the location on the hull the sample was taken from and confirms its transfer to the laboratory.

5. Information on vessel travel and maintenance history

As part of the biofouling inspection, the following information is to be collected from the vessel's captain (or nominated crew):

- Date and location of last antifouling paint renewal;

- Ports or anchorages visited since either last antifouling paint renewal or over the past 3 months (whichever was more recent), and time resided at each location (no. days). This information can be used by taxonomists to verify the identity of species collected from the hull, and to estimate their likely age, reproductive capacity and ability to survive/establish elsewhere.

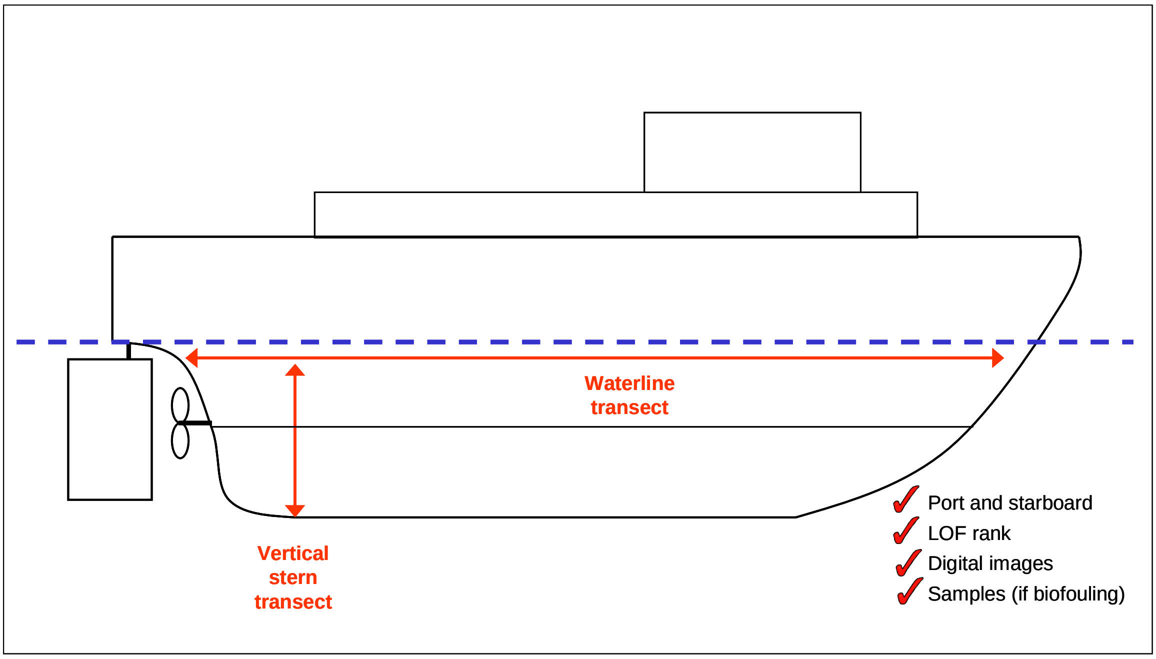

Figure 2: Biofouling inspection of general hull areas using vertical stern transects and horizontal waterline transects of both port and starboard areas.

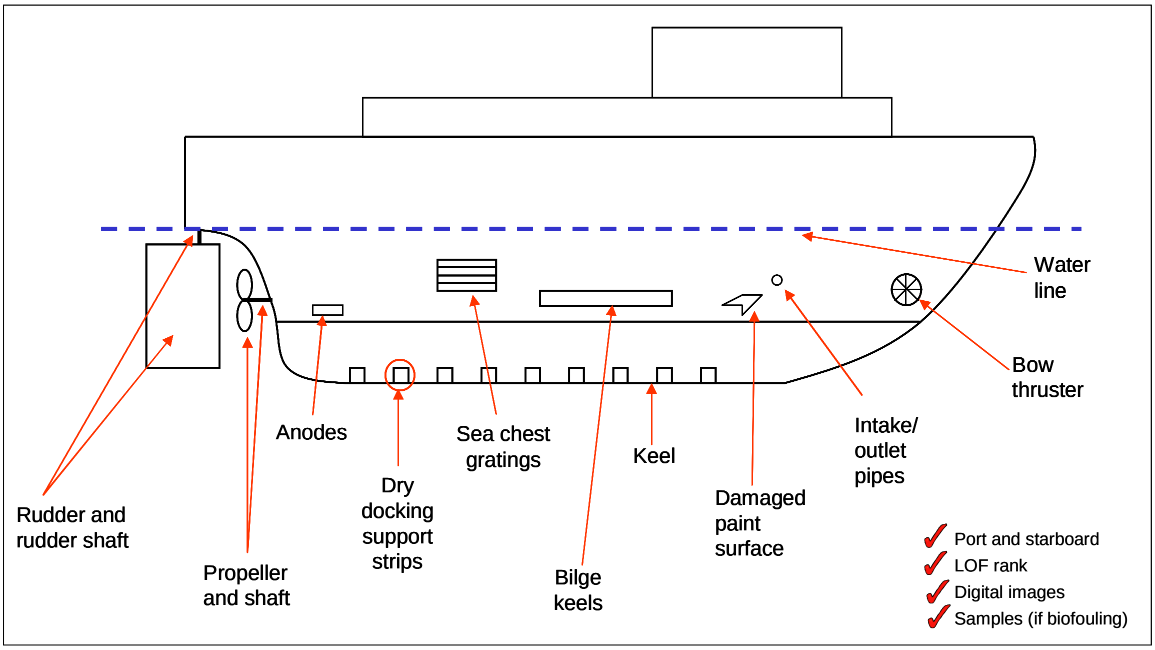

Figure 3: Biofouling inspection of niche areas.

B. Simple hull inspections for presence of biofouling

This section describes the protocols for conducting a simple inspection for the presence of biofouling as described in Section 2.1. No samples are taken during this inspection.

Requirements

Staff and equipment

The diving operation is best carried out by a team of at least two divers (SCUBA or surface-supplied diving) supported by a topside crew, ideally in a small vessel. The use of two divers is safer. Divers should be equipped with dive lights, dive knives and, ideally, a means of communication with topside personnel. Full-face dive masks with inbuilt microphones are best suited for this.

The divers should carry a digital underwater camera for taking close-up images of any biofouling organisms encountered. The camera should be equipped with an adequate strobe positioned in a way that minimises over- or underexposure of the image and back-scatter. Images taken by the camera can be used by DOC to verify the presence of biofouling.

Essential knowledge and training

Divers and surface personnel undertaking biofouling inspections need to be competent in a variety of tasks to undertake a thorough inspection following the protocols described here. Required are:

- Current OSH certification, medical clearance and commercial diving certificate (divers).
- Familiarity with all hull sampling locations, the sampling plan and the way information is captured on sample labels (divers and surface personnel).
- Some knowledge of common biofouling organisms to ensure that any biofouling organisms present are effectively detected by the divers.

Health and Safety

As described above for comprehensive biofouling inspections (Part A).

Inspection protocols

During a vessel inspection, divers will examine general hull areas and niche areas occurring around the vessel. Ideally, a plan of the ship should be consulted prior to the inspection to identify areas on the hull that need to be targeted and their exact location.

1. Inspection of general hull areas

Hull areas are inspected in the same way as described above for comprehensive hull inspections (Part A of this section). Vertical stern transects and waterline transects are completed on the port and starboard sides of the vessel. No LOF ranks are allocated or biofouling samples are to be collected at this stage. If biofouling organisms are encountered, images of the organisms are taken and a note is made of the location on the hull they were encountered in. This information can be used if divers perform in-water cleaning on the vessel at a later time to remove the biofouling detected during the inspection.

2. Inspection of niche areas

Niche areas are inspected in the same way as described above for comprehensive hull inspections (Part A of this section). No LOF ranks are allocated or biofouling samples are collected. If biofouling organisms are encountered, images of the organisms are taken and a note is made of the location on the hull they were encountered in. This information can be used if divers perform in-water cleaning on the vessel at a later time to remove the biofouling detected during the inspection.

3. Opportunistic samples

If the divers encounter biofouling outside the hull transects and niche areas listed above, images should be taken and notes made of the location of the organisms.

3.2. Protocols for sample handling, labelling, preservation and submission to taxonomic specialists

This section outlines the procedures that should be followed in topside processing of biofouling samples collected from vessel hulls during *comprehensive biofouling inspections*. Incorrect handling can render specimens unidentifiable, even by experienced taxonomists. Any organisms removed from a hull must be sorted and preserved appropriately so that their identification can be confirmed by qualified taxonomists. As hazardous substances (e.g. ethanol and formaldehyde solutions) are generally used to fix and preserve specimens collected from the hulls, the contractor must maintain appropriate Health & Safety practices in the area where the samples are processed..

Processing facilities

All biofouling samples should be kept shaded, cool and wet, and processed within 1–2 hours of collection according to the following procedures. A field lab should be set up that has:

- Sheltered, well ventilated working/bench space;
- Ready supplies of fresh salt water;
- Selection of containers for sorting (buckets, tubs, trays);
- Selection of appropriately-sized plastic vials and jars for storing samples (non-rigid clear plastic with water-tight screw caps);
- Supply of waterproof paper and pencils.

Labelling and sample registers

Accurate labelling of samples is essential. Unlabeled collections or collections with illegible (unreadable or faded printing) labels cannot be used because the information cannot be salvaged. Labels should be made from high quality, water-resistant parchment paper, light card, or archival quality paper. Write in pencil or preferably permanent ink using a pigment pen. Pens must be water- and alcohol-proof.

Labels for every sample must go inside the container, preferably so they can be read easily from outside. Permanent marker pen labels on the outside of containers may increase convenience, but are often dissolved by leaking ethanol, may be abraded by friction during transit or may be forgotten when a container is changed.

Ideally, the location and number of hull fouling samples taken should be planned in advance. However, this is not always feasible during an urgent hull inspection where the level of biofouling is unknown. In this situation, clear communication between divers and topside personnel is essential. It is important that divers relay the exact sample location (i.e. niche area, transect number, quadrat number) for each sample bag which is handed to topside personnel. Each of these samples sites should then be recorded on a sample register. This involves recording data from each field label or pre-marked collection bag on an electronic (e.g., Excel) or hardcopy registration sheet. The sample register allows the field team to track all samples collected and should be established once the hull inspection is underway.

Sorting into taxonomic groups

Once a sample has been received by topside personnel, it should be sorted into broad taxonomic groups such as algae, barnacles, crustaceans, ascidians, etc. (see Table 3).

The material in the sample bag should be emptied into a shallow tray of fresh seawater and the entire collection sorted into taxonomic groups, placing specimens from each taxon into separate, appropriately-sized containers. Keep all specimens of each group except where there are several individuals of large species. In such cases, some specimens may be discarded but care should be taken to avoid discarding new species. Decisions on which specimens to discard should be made only by an experienced scientist. If in doubt, keep all specimens.

Each taxonomic group extracted from the sample should be placed in a separate container with a separate label indicating the taxon (e.g. all the barnacles collected should be sorted into a separate container). These labels comprise the collection information, plus a 2-letter code for the taxonomic group (Table 3). If lab personnel are uncertain about what taxon a particular specimen may represent this should be identified accordingly on the sample label (e.g. “Sponge? Taxon unknown.”).

Each preserved, sorted collection should be recorded in the sample register as it provides a record of all samples that leave the field laboratory and allows easy tracking from the field laboratory to the taxonomic service providing the identification. It is recommended that reference specimens of any distinct taxa be photographed. Each photo should include a scale bar and a visible label with the collection information and taxon codes adjacent to each specimen. Create a record of the image file number associating it with the collection code, in case the label is not legible within the image.

Fixatives and preservatives

All specimens should be fixed and preserved as soon as possible. See Table 3 for fixation requirements specific to each taxon group. Do not use isopropyl alcohol (IPA) for fixing or preserving any specimens. Formalin should be diluted to 5 % or 10 % using seawater, not freshwater. Ethanol must be diluted using freshwater, not seawater.

Each sorted collection should be placed in at least five times its own volume of preservative so that water in the specimens’ tissues does not dilute the preservative.

Where fixatives or preservatives are not available, sorted and labelled specimens can be kept wet (preferably in a container/jar filled with fresh seawater), and kept chilled (*not frozen*) until fixatives are available. However, this period should not exceed 24 hours post-collection or the integrity of the specimens will be compromised.

Health and Safety

When using ethanol or formalin, ensure the area is well ventilated and away from electrical appliances (such as laptops).

- Formalin is a Class 9 hazardous substance (ecotoxic and corrosive). When formalin is used at 5 or 10% dilution, it may cause skin irritation and burns to the skin and eyes. Therefore it is recommended that nitrile gloves, protective clothing (i.e. long sleeves which cover skin) and safety glasses are used. Immediately clean up spills and discard of waste in approved manner.

- Ethanol is a Class 3 flammable liquid and care must be taken to avoid use within the vicinity of sparks, electrical appliances or ignition sources. Immediately wipe up spills. Ventilation is important as vapours may cause dizziness. Skin exposure may result in irritation or mild burns, particularly to eyes. Again, it is recommended that nitrile gloves, protective clothing and safety glasses are used.

Neither of these substances should be spilt or released into the marine environment.

Shipping and Handling

Prepare samples for shipping by packing containers/jars in plastic bags (including absorbent packaging to minimize damage caused by any leakage), then into larger, tougher plastic bags, buckets or plastic bins. Seal properly. If samples have been preserved or fixed prior to shipping, they must be sent with an approved Dangerous Goods transporter (e.g. Chem Couriers). A shipper's declaration, specific dangerous goods emergency response procedures and supporting documentation will be required.

Table 3: Taxonomic groups into which all collections should be sorted, their taxon code for labelling, and fixation requirements. An asterisk (*) denotes a requirement to transfer sample into 70 % ethanol within 1–4 days.

Taxon	Sorting groups	Taxon Code	Fixative and/or preservative	Conc.
Algae	Algae	AG	Formalin	5 %
Ascidians	Colonial ascidians	AN	Formalin	10 %
	Solitary ascidians	AN	Ethanol	70 %
Bryozoa	Bryozoa	BR	Ethanol	70 %
Crustacea	Amphipods	AM	Ethanol	70 %
	Barnacles	BN	Ethanol	70 %
	Crabs	CB	Ethanol	70 %
	Other decapods	DP	Ethanol	70 %
	Isopods	IS	Ethanol	70 %
	Ostracods	OS	Ethanol	70 %
	Tanaids	TN	Ethanol	70 %
Cnidaria	Ctenophores	CN	Formalin	10 %
	Hydroids	HY	Formalin	10 %
	Hard corals	HC	Ethanol	70 %
	Sea anemones	SN	Formalin	10 %
	Soft corals	SF	Formalin*	10 %
	Jellyfish	JF	Formalin	10 %
Echinoderms	Brittle stars	BS	Ethanol	70 %
	Echinoids	EC	Ethanol	70 %
	Holothurians	HT	Ethanol	70 %
	Sea stars	SS	Ethanol	70 %
Fishes	Fishes	FH	Formalin	10 %
Molluscs	Bivalves	BV	Ethanol	70 %
	Gastropods	GP	Ethanol	70 %
	Other molluscs (shell)	MU	Ethanol	70 %
	Other molluscs (no shell)	MU	Formalin*	10 %
	Polyplacophorans/chitons	PO	Ethanol	70 %
	Opisthobranchs (no shell)	OB	Formalin*	10 %
Pycongonids	Pycongonids	PY	Ethanol	70 %
Sponges	Sponges	SP	Ethanol	70 %
Flatworms	Flatworms	FW	Formalin	10 %
Annelid worms	Annelid worms	WM	Formalin	10 %
Nemerteans	Nemertean worms	NT	Formalin	10 %
Sipunculans	Sipunculan worms	SI	Formalin	10 %
Washings	Residues from sorting	WH	Formalin	10 %
Unknown	Unknown	UK	Formalin	10 %

3.3 Information required from the taxonomic specialists

The risk the biofouling species present on a vessel pose to the sub-Antarctic or Kermadec islands is governed by a range of factors pertaining to their abundance, age (or level of maturity), biogeography, environmental tolerance, habitat requirements and invasive history in other locations. When samples from a biofouling inspection are submitted to taxonomic specialists, they must be accompanied by clear instructions on what information the taxonomists are expected to provide as part of their identification of each species. Conversely, as described in Sections 2.1 and 2.2 above, it is important that the taxonomists are provided with all information required for their identification process (e.g. the travel history of the vessel).

The following information is required from the taxonomists, for each species they identify from the specimens collected during the hull inspection (see Table 4 for an example):

a) Name of taxonomic expert who identified the sample;

b) Species name and common name (if there is one);

c) Details of the samples each of the species was encountered in;

d) Native and introduced range of the species (broad geographic regions, where known);

e) Presence/absence of each species in mainland New Zealand (North/South Islands)

f) Biosecurity status of each species in mainland New Zealand (indigenous, non-indigenous, cryptogenic);

g) Presence/absence in the Kermadec islands and/or those sub-Antarctic islands the vessel intends to visit. If a species is non-indigenous *and* already present in the islands, information on its distribution if available;

h) Biosecurity status in the Kermadec islands and/or those sub-Antarctic islands the vessel intends to visit;

i) Potential for establishment and proliferation in sub-Antarctic and Kermadec islands based on environmental tolerance and habitat requirements (categories: unlikely, possible, likely);

j) Age and maturity of specimens examined (e.g. non-reproductive juveniles; adults; presence of eggs/larvae), where possible;

k) Perceived risk posed to sub-Antarctic and Kermadec islands (negligible, low, moderate, high), and justification of this estimated risk. Note that the risk posed by a non-indigenous species that is *already known* to occur in the Sub-Antarctic or Kermadec islands should not by default be regarded as low (due to the species already being established. An example is *Undaria pinnatifida* – present in the Snares Islands but not known from any other islands).

Table 4: Example of an information table to be completed by taxonomists for all species identified from biofouling samples removed from a fictional vessel, the *MV Sub-Antarctic Explorer*.

Species	Presence in samples	Native range	Introduced range	Presence mainland NZ	Biosecurity status mainland NZ	Presence Sub-Ant./ Kerm. Isls.	Biosecurity status Sub-Ant./ Kerm. Isls.	Potential to establish, survive, reproduce in Sub-Ant./ Kerm. Isls.	Age/maturity of material examined (where possible)	Perceived overall risk posed to Subs/Kerm
Lepas anatifera (goose barnacle)	SAE-RS-1; SAE-DS-2 SAE-T2-PL	Cosmopolitan		Present in North and South Island	Indigenous	Present in Sub-Ant. and Kerm. islands	Indigenous	Already established	Mature adults	Negligible as indigenous to these locations
Undaria pinnatifida (Asian kelp)	SAE-RS-1	Asia	Mediterranean, New Zealand, Australia, Argentina	Present in North and South Island	Non-indigenous (invasive)	Present in the Snares Islands	Non-indigenous	Could establish and proliferate	Reproductive specimen	High-Extreme as non-indigenous, notorious invasive species, suitable for Sub-Ant/Kerm environment
Species 3										
Species 4										

3.4 Reporting templates for biofouling inspection

This section contains suggested reporting templates that companies carrying out (i) comprehensive biofouling inspections, or (ii) simple inspections for the presence of biofouling need to complete and submit to DOC.

A. Comprehensive biofouling inspection – report form

This form must be completed by the company contracted to undertake a comprehensive vessel biofouling inspection and risk assessment.

The responsibilities of the inspector are to:

1. Undertake a vessel biofouling inspection following the protocols outlined below (including the provision of all required equipment);
2. Arrange for taxonomic identification of specimens collected during the inspection *by recognised taxonomic specialists*;
3. Ensure that the taxonomic specialists conducting the identification provide all of the information required on the biogeography of each species and the level of biosecurity it poses to the sub-Antarctic or Kermadec islands.

The following resources must be used during the inspection and risk assessment and are provided by the Department of Conservation:

1. Sampling protocols for hull inspections (including protocols for LOF allocation);
2. Laboratory and sample management protocols;
3. Template for information to be provided by taxonomists (Section 2.3 in this report)

A. Vessel details and inspection summary

Contact details

1. Vessel name: →
2. Date and location of inspection: →
3. Inspecting company, representative and contact details: →
4. Vessel captain or crew representative and contact details →

Maintenance and travel history

5. Date of last antifouling paint renewal: →
6. Date and location of last in-water inspection, brief description of results and treatment undertaken: →
7. Ports and countries visited in past 3 months or since past antifouling paint renewal (whichever was more recent): →

Main inspection results

8. Were biofouling organisms encountered on the vessel? →
9. What is the vessel's overall biofouling extent. Provide average LOF rank allocated during sampling, also provide maximum LOF rank allocated to any area inspected: →
10. Were species with a moderate or high biosecurity risk to the sub-Antarctic or Kermadec islands encountered? If yes, how many species? →

B. Results of taxonomic identification of biofouling samples

Authority that conducted the identification:

Contact person and contact details:

TABLE OF SPECIES IDENTIFIED FROM VESSEL

Species (scientific and common name)	**Native range**	**Introduced range**	**Presence mainland NZ**	**Biosecurity status mainland NZ** (native, non-indigenous, cryptogenic)	**Presence Subs/Kerm**	**Biosecurity status Subs/Kerm** (native, non-indigenous, cryptogenic)	**Potential to establish, survive, reproduce in Subs/Kerm**	**Age/maturity of material examined**	**Perceived overall risk posed to Subs/Kerm** (negligible, low, moderate, high)	**Risk justification**
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										

Continue table on new page if required.

C. Overview of sampling and biofouling distribution

HULL AREAS

	Side of vessel	Done? (Y/N)	LOF rank (0-5)	Biofouling taxa detected (e.g. barnacles, algae, bivalves)	High-risk non-indigenous species detected? Provide names.
1. Vertical stern transect	Port				
	Starboard				
2. Waterline transect	Port				
	Starboard				
3. Opportunistic collections					

NICHE AREAS

Niche area (add others if applicable)	**Niche present (Y/N)?; side of vessel**	**Inspec-ted?** (Y/N)	**LOF rank** (0-5)	**Biofouling taxa detected** (e.g. barnacles, algae, bivalves)	**High-risk non-indigenous species detected?** Provide names.
Rudder and shaft					
Propeller and shaft					
Anodes 1. 2. 3. 4.					
Dry-docking support strips					
Sea chest gratings 1. 2. 3. 4.					
Intake/outflow openings 1. 2. 3. 4.					

Niche area (add others if applicable)	**Niche present (Y/N)?; side of vessel**	**Inspec-ted?** (Y/N)	**LOF rank** (0-5)	**Biofouling taxa detected** (e.g. barnacles, algae, bivalves)	**High-risk non-indigenous species detected?** Provide names.
Bilge keels					
Bow thruster					
Damaged paint surfaces 1. 2. 3. 4.					

B. Simple inspection (presence of biofouling)– report form

This form must be completed by the company contracted to undertake a vessel biofouling inspection.

- The responsibilities of the inspector are to undertake a vessel inspection to determine whether biofouling is present on the vessel.

The following resources must be used during the inspection and are provided by the Department of Conservation:

- Hull inspection protocols (simple inspection);

A. Vessel details and inspection summary (simple inspection)

Contact details

1.	Vessel name:	→
2.	Date and location of inspection:	→
3.	Inspecting company, representative and contact details:	→
4.	Vessel captain or crew representative and contact details	→

Maintenance and travel history

5.	Date of last antifouling paint renewal:	→
6.	Date and location of last in-water inspection, brief description of results and treatment undertaken:	→
7.	Ports and countries visited in past 3 months or since past antifouling paint renewal (whichever was more recent):	→

Main inspection results

8.	Were biofouling organisms encountered on the vessel?	→

B. Overview of biofouling distribution

HULL AREAS

	Side of vessel	Done? (Y/N)	Biofouling detected?
1. Vertical stern transect	Port		
	Starboard		
2. Waterline transect	Port		
	Starboard		
3. Opportunistic collections			

NICHE AREAS

Niche area (add others if applicable)	**Niche present (Y/N)?; side of vessel**	**Inspected? (Y/N)**	**Biofouling detected?**
Rudder and shaft			
Propeller and shaft			
Anodes 1. 2. 3. 4.			
Dry-docking support strips			
Sea chest gratings 1. 2. 3. 4.			
Intake/outflow openings 1. 2. 3. 4.			
Bilge keels			
Bow thruster			
Damaged paint surfaces 1. 2. 3. 4.			

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5. Appendix 1: Using the Level of Fouling (LOF) rank index to quantify biofouling on vessel hulls

The LOF scale was developed by NIWA as a quick and effective method of quantifying biofouling on vessel hulls (Floerl et al. 2005, *Environmental Management*, Volume 35 (issue 6), pages 765-778). It has since been used in NIWA's own biofouling research projects as well as projects commissioned by MAF Biosecurity New Zealand.

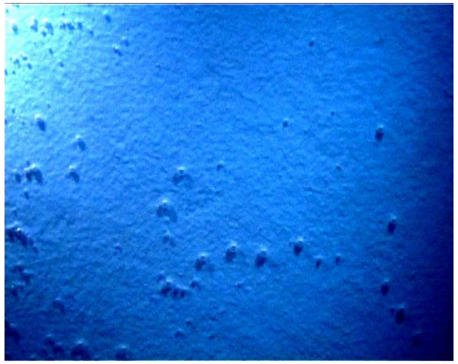
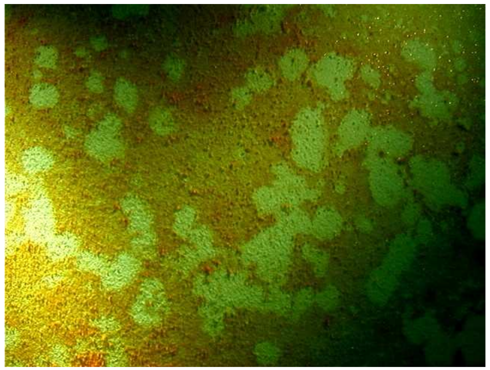
LOF ranks range from 0 to 5 and the various ranks along with example images for hull biofouling assemblages are provided in Table 5. One particularly important fact about the LOF scale is that so-called macrofouling organisms (e.g. barnacles, tubeworms, bivalves, etc.) are <u>absent</u> from areas defined as LOF rank 0 (entirely free of biofouling) and 1 (slime fouling only). That means that the lowest LOF rank that can be allocated to an area where there is a single barnacle, bivalve or other macrofouling organism, is a LOF rank of 2.

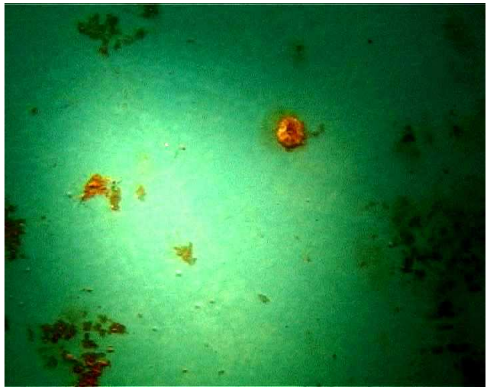
The use of the LOF scale is simple and quick and <u>based on both (i) the areal extent, and (ii) the diversity of biofouling in a target area</u>. Divers that have been trained in the use of the scale should be able to allocate LOF ranks confidently and consistently, with minimal variation among observers.

During a vessel inspection, a LOF rank is allocated to the entire area under inspection, i.e. a niche area or a hull transect. Using a vessel's propeller as an example: the entire propeller (blades, boss, shaft) is examined and a single LOF rank is allocated based on the entire structure. Similarly, a single LOF rank is allocated to the vertical stern transect, and to each of the stern, amidships or bow segments of the waterline transect).

NIWA advises that commercial dive teams and topside field officers carrying out vessel inspections should be trained in the use of the LOF rank scale. NIWA can provide this training via small workshops.

Table 5: Definition of the LOF ranks (ranging from 0 to 5) and example images of vessel hull surfaces of each of the different ranks.

LOF rank	Criteria	
0	No visible biofouling. Hull entirely clean, no slime fouling (biofilm) on any visible submerged parts of the hull.	
		
1	Hull partially or completely covered in slime fouling (biofilm). Absence of any macrofouling.	
		

LOF rank	Criteria
2	Light biofouling. 1 – 5 % of visible surface covered by very patchy macrofouling. Remaining area often covered in slime. Examples below show presence vs. absence of fouling in two adjacent areas of a vessel hull.  
3	Moderate biofouling. Macrofouling clearly visible (usually > 1 species) but still patchy. 6 – 15 % of visible hull surface covered by macrofouling. Remaining area often covered in slime.  

LOF rank	Criteria
4	Extensive fouling. 16 – 40 % of visible hull surface covered by macrofouling, generally several distinct types of organisms. Remaining area often covered in slime.  
5	Very heavy fouling. 41 – 100 % of visible hull surface covered by macrofouling, often many distinct types of organisms. Remaining area often covered in slime.  

6. Appendix 2: Risk factors omitted from our evaluation of a vessel's biosecurity risk

We have not included a number of factors in our evaluation of risk and provide a list of these and a justification for their exclusion below:

(i) Reproductive state of the species. The immediate biosecurity risk may differ between juvenile (reproductively immature) and adult (mature) individuals of a species. However, determining the reproductive status of a potentially large number of specimens is labour-intensive, expensive and beyond the scope of the inspections envisaged by DOC. We focused our evaluation on factors that can be included in an efficient and cost-effective examination of specimens.

(ii) Reproductive mode of the species. Species that are able to self-fertilise and/or brood larvae may require fewer individuals on a hull for establishment at a destination than species relying on release and external fertilisation of gametes. However, as our evaluation does not strive to provide a measure of the likelihood of establishment, and as the objective of the risk assessment is to prevent the establishment of any NIS in New Zealand's remote island locations, we used a conservative approach and treated all reproductive modes as equally risky.

(iii) Dispersal distance. Some species have dispersal stages that remain in the plankton for weeks and can travel long distances, while other propagules have shorter planktonic lives of a few hours. Yet others – e.g. mobile species – may simply 'drop off' a hull and sink into the recipient habitat. However, because of the uncertainty regarding nearshore currents in the various island locations (velocity, direction, onshore vs. offshore drift, etc.) and the distance different vessels keep from shore, we excluded this factor from our evaluation and treated all dispersal strategies as equally risky.

(iv) Number of NIS detected by the survey. We attributed biosecurity risk to a vessel based on the identity of the individual NIS detected on the hull, not their number. A vessel carrying a single high-risk NIS is attributed the same level of risk as a vessel that carries 10 high-risk NIS.